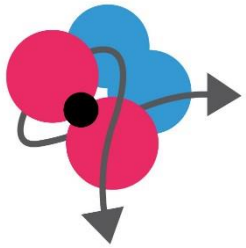
ELEGANCY
Enabling a Low-Carbon Economy via Hydrogen and CCS



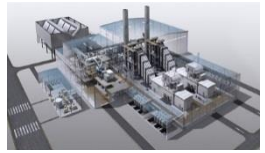
Svend Tollak Munkejord, SINTEF Energy Research, project coordinator

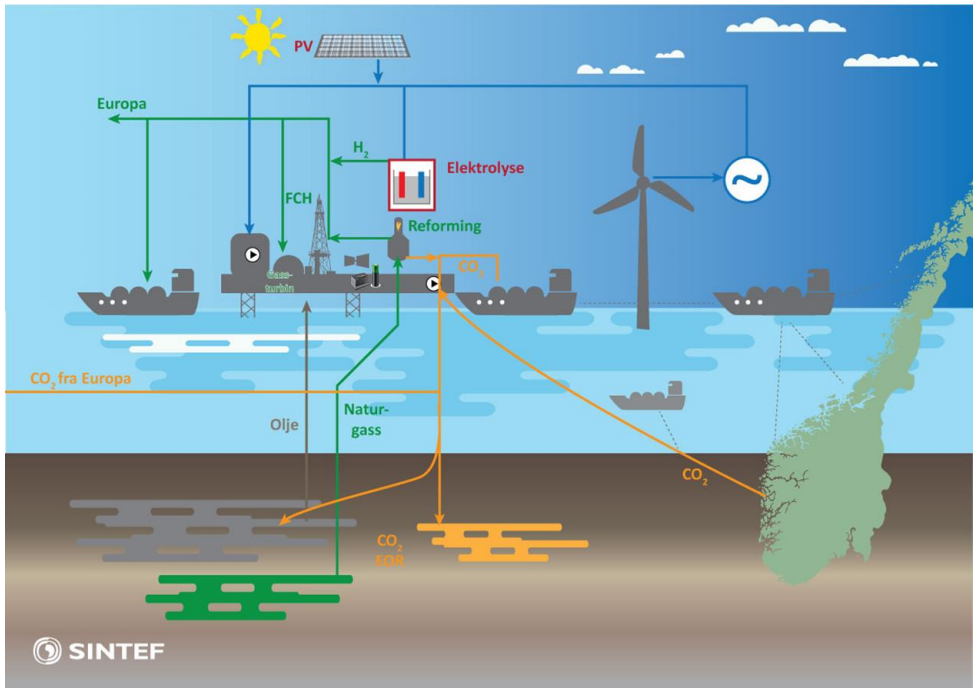
ACT knowledge-sharing workshop, Bucharest, 2017-10-24

Outline of presentation

- Project context and overview
- Contents of work packages
- Status

ELEGANCY – Context

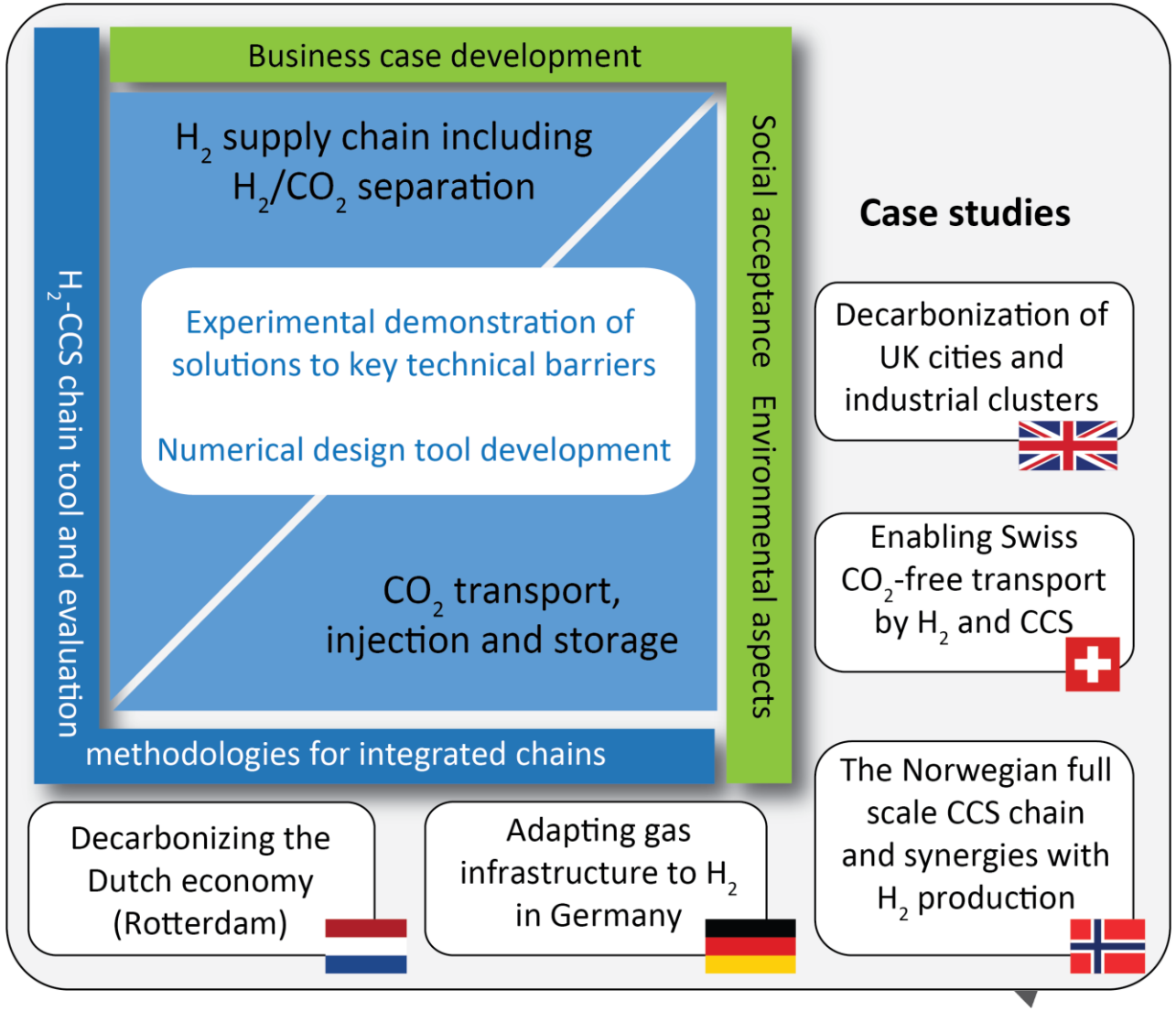




- The low carbon economy needs hydrogen for:
  - Industrial decarbonization
  - Heating and cooling
  - Transport (Marine, Rail, heavy trucks and cars)
- The low carbon economy needs CCS to:
  - Decarbonize industrial emissions
  - Provide a credible carbon negative solution
  - Provide the speed needed in the energy and climate transformation
- Combining hydrogen with CCS offers an exiting opportunity for synergies and value creation
  - Common use of infrastructure and the same offering to the end-user
  - Flexible hydrogen production offering balancing value to the grid
  - Value creation and sustainability from domestic assets on a long term scale
  - Could provide Europe with a unique position in industry, heating and cooling and transport by enabling massive amounts of hydrogen for various uses in society
- ELEGANCY aims at providing stepping stones essential in the realization of the energy system of the future
  - Efficient value chains for large scale hydrogen deployment- the merger of CCS and renewables in the society
  - Solving key technical barriers and providing experimentally validated tools for design of safe and efficient chain elements
  - Enable a credible path for the hydrogen/CCS transition and role in the future low carbon society

ELEGANCY – key information

- Primary objective: Fast-track the decarbonization of Europe's energy system by exploiting the synergies between two key low-carbon technologies: CCS and H_2.
- Duration: 2017-08-31 to 2020-08-31.
- Preliminary budget: 15 643 kEUR.
- Partners:
  - NO: SINTEF Energy Research, AdeB, AKSO, Gassco
  - UK: ICL, BGS, SDL, Scottish Enterprise, INEOS
  - CH: ETH, PSI, Climeworks, First Climate
  - NL: ECN, TNO, UU
  - DE: RUB, Open Grid Europe, Uniper Energy Storage
  - GERG, Swerea-MEFOS



ELEGANCY – objectives

Fast-track the decarbonization of Europe's energy system by exploiting the synergies between two key low-carbon technologies: CCS and H_2. To this end, **ELEGANCY will:**

- Develop and demonstrate effective CCS technologies with high industrial relevance
- Identify and promote business opportunities for industrial CCS enabled by H_2 as a key energy carrier by performing 5 national case studies
- Validate key elements of the CCS chain by frontier pilot- and laboratory-scale experiments using inter alia ECCSEL and EPOS research infrastructure
- Optimize combined systems for H_2 production and H_2-CO_2 separation
- De-risk storage of CO_2 from H_2 production by providing experimental data and validated models
- Develop simulators enabling safe, cost-efficient design and operation of key elements of the CCS chain
- Provide an open source techno-economic design and operation simulation tool for the full CCS chain, including H_2 as energy carrier
- Assess societal support of key elements of CCS

ELEGANCY – work packages & chains

Case studies incl. social acceptance, environmental aspects and CCS-H_2 market considerations: UK (large-scale decarbonization), Netherlands (Rotterdam decarbonization), Norway (full scale CCS chain and H_2 production), Switzerland (decarbonization of transport sector), Germany (adapting gas infrastructure and processes to H_2) **WP5**

H_2-CCS chain tool and evaluation methodologies for integrated chains: (ICL, SINTEF, PSI, RUB, TNO) **WP4**

Business case development: (AdeB,FirstClimate,SDL) **WP3**

H_2 supply chain including H_2/CO_2 separation

WP1

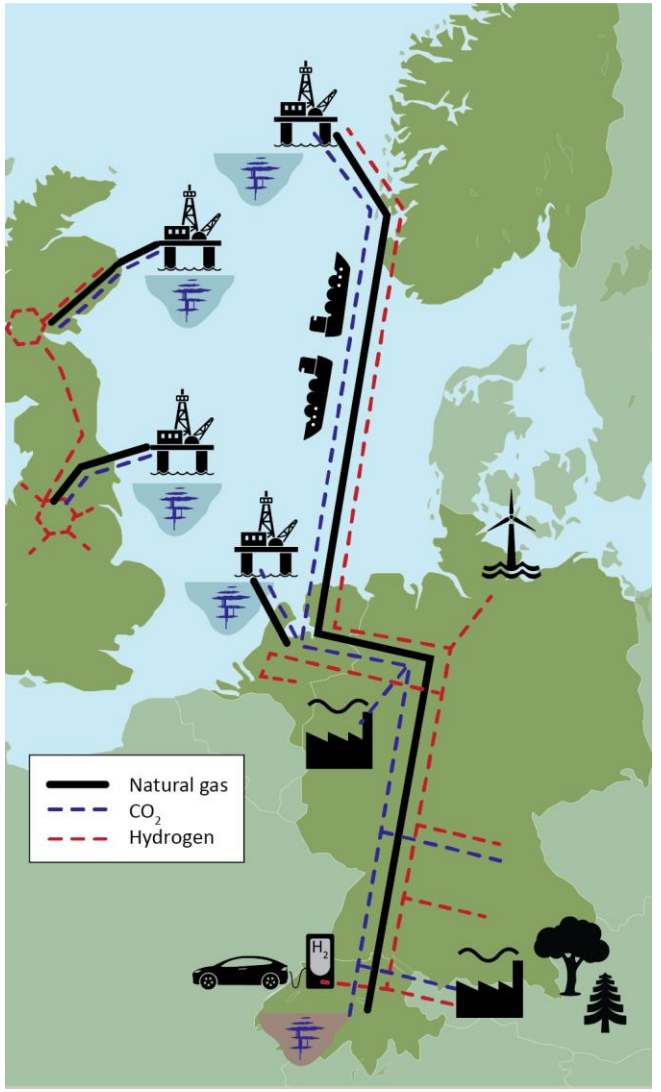
- H_2 from natural gas (ETH, PSI)
- H_2 from other sources (ECN)
- Characterization of CO_2-CO-H_2 mixtures (RUB)

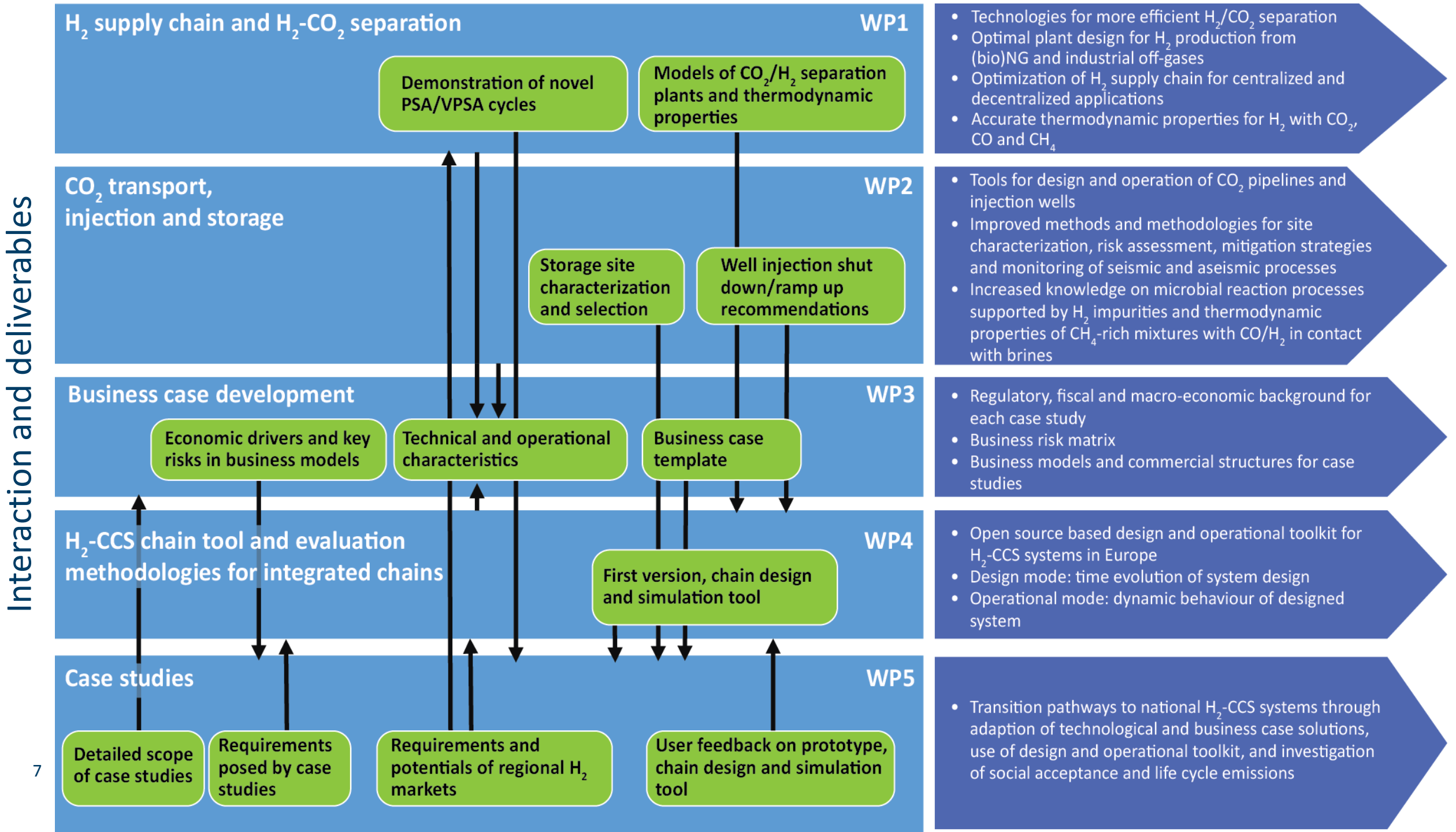
CO_2 transport, injection and storage

WP2

- CO_2-brine model (RUB,ICL)
- CO_2 transport-injection interface (SINTEF)
- Storage-site characterization and selection (ICL)
- Mt. Terri decametre scale experiment (ETH)
- Impact of H_2 in the CO_2 stream on storage (BGS)
- De-risking storage

ELEGANCY project management, network building and dissemination (SINTEF) **WP6**

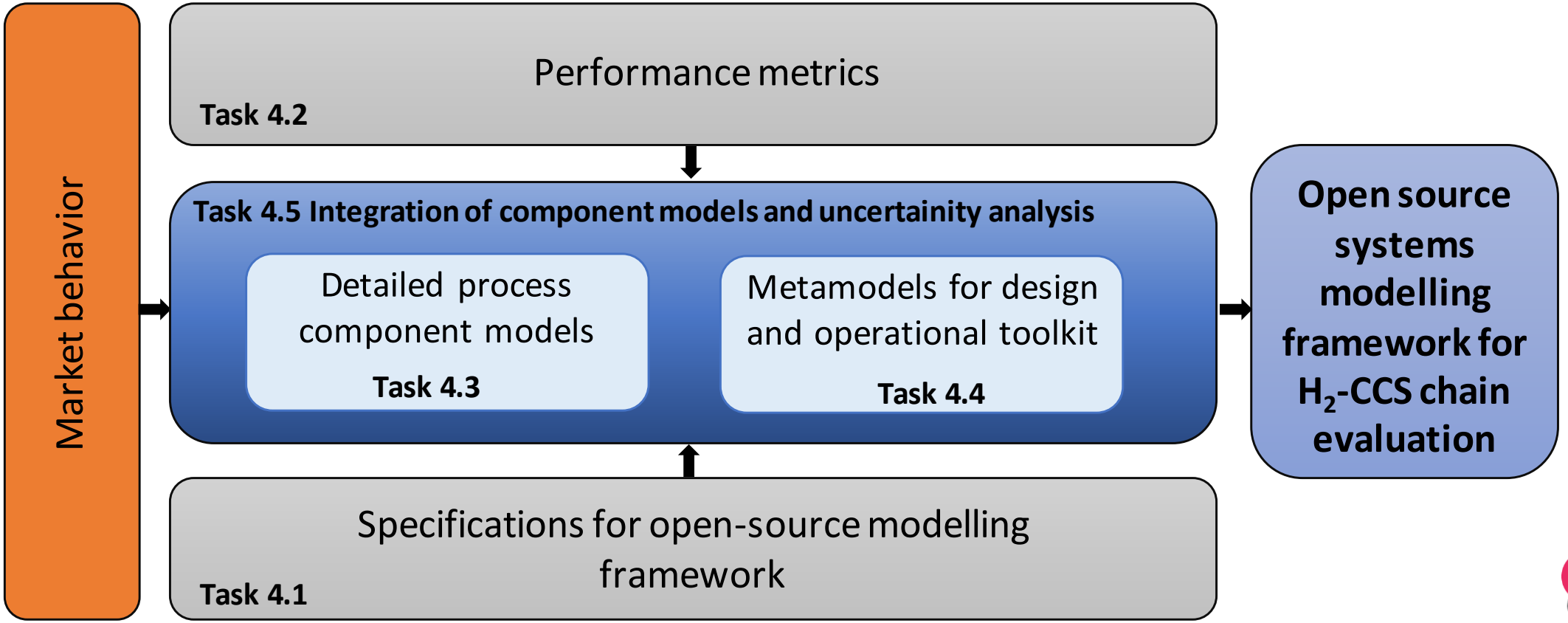



Interaction and deliverables
H2 supply chain and H2-CO2 separation
WP1
Demonstration of novel PSA/VPSA cycles
Models of CO2/H2 separation plants and thermodynamic properties
CO2 transport, injection and storage
WP2
Storage site characterization and selection
Well injection shut down/ramp up recommendations
Business case development
WP3
Economic drivers and key risks in business models
Technical and operational characteristics
Business case template
H2-CCS chain tool and evaluation methodologies for integrated chains
WP4
First version, chain design and simulation tool
Case studies
WP5
Detailed scope of case studies
Requirements posed by case studies
Requirements and potentials of regional H2 markets
User feedback on prototype, chain design and simulation tool
• Technologies for more efficient H2/CO2 separation
• Optimal plant design for H2 production from (bio)NG and industrial off-gases
• Optimization of H2 supply chain for centralized and decentralized applications
• Accurate thermodynamic properties for H2 with CO2, CO and CH4
• Tools for design and operation of CO2 pipelines and injection wells
• Improved methods and methodologies for site characterization, risk assessment, mitigation strategies and monitoring of seismic and aseismic processes
• Increased knowledge on microbial reaction processes supported by H2 impurities and thermodynamic properties of CH4-rich mixtures with CO/H2 in contact with brines
• Regulatory, fiscal and macro-economic background for each case study
• Business risk matrix
• Business models and commercial structures for case studies
• Open source based design and operational toolkit for H2-CCS systems in Europe
• Design mode: time evolution of system design
• Operational mode: dynamic behaviour of designed system
• Transition pathways to national H2-CCS systems through adaption of technological and business case solutions, use of design and operational toolkit, and investigation of social acceptance and life cycle emissions

World-class research infrastructure

Description	Scale	Partner
Adsorption infrastructure (ECCSEL)	Lab-scale	ETH
Cycling adsorbent analyser	Lab-scale	ECN
Single- and multi-column reactive PSA/TSA equipment	Pre-pilot, TRL 5	ECN
Equipment for measurements of density, speed of sound and dielectric permittivity	Lab-scale	RUB
Vertical flow facility	Pilot-scale	SINTEF
Pipe and vessel depressurization (ECCSEL)	Lab-scale	SINTEF
Core-flooding laboratory	Lab-scale	ICL
Batch-reactor for mineral-dissolution kinetics	Lab-scale	ICL
Equipment for measurements of CO_2-brine-mineral contact angle, interfacial tension and phase behaviour	Lab-scale	ICL
Hydrothermal laboratory (ECCSEL)	Lab-scale	BGS
Geo-microbiology laboratory (ECCSEL)	Lab-scale	BGS
Rock deformation laboratory (ECCSEL)	Lab-scale	SCCER
Micro-seismic monitoring arrays	Lab-scale	SCCER
Mt. Terri research rock laboratory (EPOS)	Pilot-scale	SCCER

H_2-CCS chain tool and evaluation methodologies for integrated chains



WP1: H_2 supply chain and H_2-CO_2 separation

- **ETH**, PSI, ECN, MEFOS, RUB, UU
- Enable efficient H_2 production and CO_2 capture at different plant sizes.
- Find ways to increase the efficiency and productivity of natural gas/biogas reforming and CO_2/H_2 separation independently of the plant size.
- Integrate H_2 production and CO_2 capture with significant industrial processes such as steel production
- Characterize the properties of H_2 mixed with CO_2, CO, and CH_4.
- The research spans the range from the phenomenon level (RUB) via lab-scale experiments (ETH and ECN) to the pre-pilot scale (ECN).

WP2: CO_2 transport, injection and storage

- **SINTEF**, BGS, SCCER, ICL, RUB – *De-risk storage*.
- Develop an accurate property model for CO_2-brine in the presence of impurities.
- Mature and validate tools for the safe, efficient and cost-effective design and operation of CO_2 pipelines and injection wells.
- Perform petrophysical chemical analyses for the characterization and selection of storage sites in Switzerland.
- Design and perform decameter-scale experiments at the Mt Terri research rock laboratory.
- Reduce uncertainties in injection, storage and monitoring of CO_2 produced by NG reforming for H_2 production.

WP3: Business case development for H_2-CCS integrated chains

- **AdeB**, SDL, FC
- Assess the regulatory background, identify barriers, mitigation strategies and opportunities for H_2-CCS.
- Assess the macro-economic, market and fiscal background to identify plausible business models.
- Develop business models and business case templates for use in the WP5 case studies.

WP4: H_2-CCS chain tool and evaluation methodologies for integrated chains

- **ICL**, SINTEF, PSI, RUB, TNO
- Enable the evaluation of integrated H_2-CCS chains with respect to technological and economic efficiency, operability and environmental impact
- Develop an open-source systems modelling framework with a steady-state design mode and a dynamic operational mode.
- Develop multiscale models and an integrated modelling approach for the chain components incorporating results from WP1 and WP2.
- Apply the methodology in conjunction with the case studies in WP5 with respect to (i) the potential time evolution of the system and (ii) integrated assessments of proposed designs.

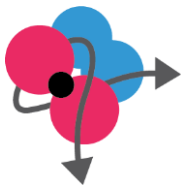
WP5: Case studies

- **SINTEF**, BGS, TNO, UU, ECN, RUB, PSI, ICL, SDL, ETH, SCCER, CW, FC, INEOS, SE, AKSO, GERG
- Develop a roadmap for decarbonizing the Rotterdam industry
- Decarbonize the Swiss transport sector and prepare the way for a Swiss CO_2 storage site
- Support the UK H21 roadmap
- Decarbonize German natural gas as an energy carrier
- Evaluate the benefit of converting Norway's NG resources to H_2 with CCS

Status

- 1. August: Consortium Agreement signed
- 8 September: ACT R&D Project Agreement Document signed
- 19–20 September: Kick-off meeting (Brussels)
- ELEGANCY has a
  - relevant
  - ambitious
  - high quality

  work plan.
- I think we can make a difference.



Acknowledgement

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